Volume 34 December, 1948 *Number 12*

Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

THE DEVELOPMENT
OF A
NEW GREASE

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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The Development of a New Grease

MANY years ago, the lubrication of industrial machinery and transportation equipment was a simple matter. Motive power was furnished by water or air, by mules or horses, or by man.

All types of equipment were slow in motion, machining methods were crude and simple, and bearings were rough and loose fitting. Occasional application of lard oil or tallow sufficed to maintain the slow pace of the premechanized era.

The transition from low speed to high speed, from crudity to precision, from manpower to mechanical power, and from the spasmodic and ineffectual hand lubrication of moving parts with tallow to the application of highly specialized greases by automatic lubricators came very gradually at first. But in recent years progress in these fields has advanced at an ever increasing rate. During the early days of the current century and before, lubricants were developed only as products for general application. Today the petroleum industry tailors lubricants to fit the many special needs which arise in the course of mechanical development.

To keep pace with the great forward strides of technological advancement, every large producer of petroleum products maintains a staff of highly trained specialists who devote their talents to the development of new lubricants in a constant battle against man's great friend and enemy, friction.

Many new types of equipment and many new mechanical devices have been developed during recent years. To most people, however, the giant high speed diesel locomotives that thunder across the nation, the new planes that traverse continents and oceans in only a few hours time, or the new washing machines that lighten the work of the housewife with completely automatic operation, are but the expected manifestations of our advancing civilization. Few indeed understand the mechanical principles of their operation and fewer still give any thought to the lubrication of these devices. Modern lubricants perform their functions so smoothly that to the average man lubrication is no problem and he is concerned only when he is reminded by the corner filling station attendant that his car needs oil.

To the designing engineer, to the mechanical engineer, and to maintenance personnel, lubrication is a matter of deepest concern. To the lubricants research scientist, it is a challenge requiring a never ending search for better materials and combinations of materials to overcome the frictional forces which inevitably arise between surfaces moving against one another. In order to lubricate successfully the many new devices now appearing on the market, special oils and greases are necessary; the story of how a new grease comes into being is as interesting as the story of the development of the new equipment on which it is to be used.

THE BEGINNING OF THE STORY

The story of a new grease often begins when some new type of mechanical device is first placed on the drawing board, for at that point a problem of lubrication may become apparent. Some new set of conditions – high temperatures, low temperatures, extreme centrifugal forces, excessive water washing conditions, extreme pressure, longevity of service in inaccessible places or a multitude of other factors may demand a grease having properties unlike any yet available. The grease technologist is then called in and the requirements of the new

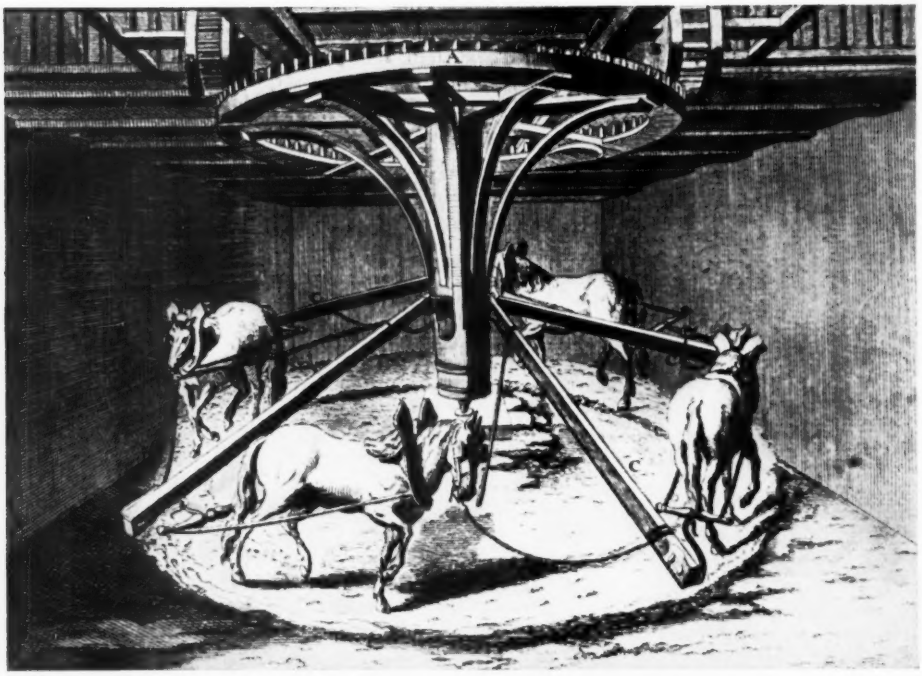


Figure 1—Showing the application of actual horse-power in a 17th Century mill.

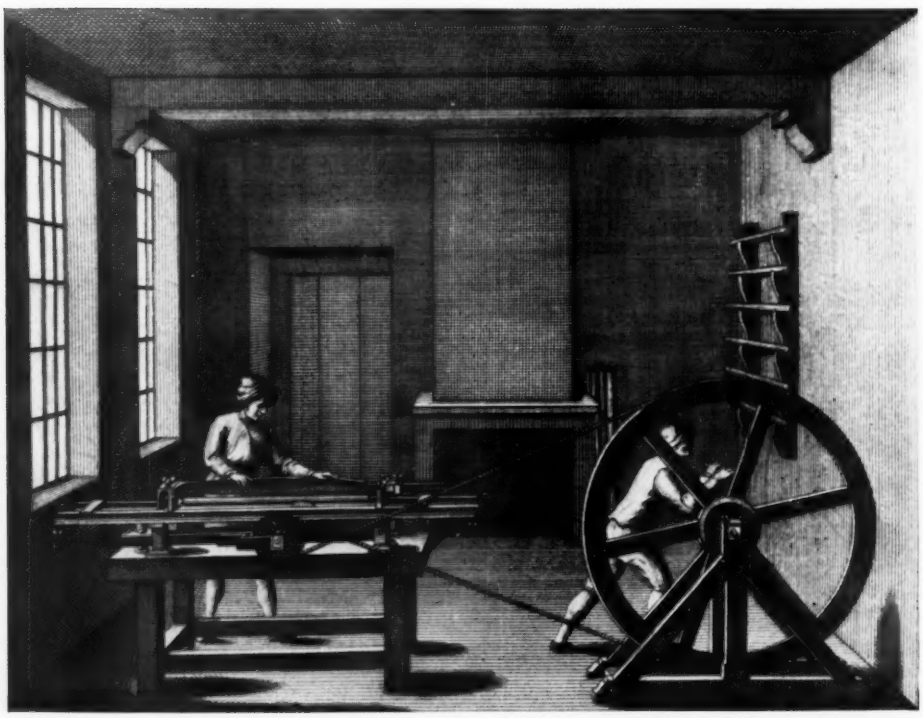


Figure 2—Showing how human power (supplied by the boy at the right) was multiplied by complicated sets of wheels, pulleys and levers, in years gone by.

lubricant are outlined to him. Armed with this information, he then begins the work of developing the new grease.

The Nature of Greases

Greases are essentially mixtures of oils and soap in which may be incorporated special additives and other materials. They are not, however, simple mixtures. On the contrary, they are exceedingly complex, multiple-phase systems of which little of the true physico-chemical nature is even yet known. The problem facing the research technologist is not, therefore, simple or easy of solution. Very careful consideration must be given to the ingredients which must be used to make a product having the desired characteristics, as well as to the methods to be used in combining these ingredients.

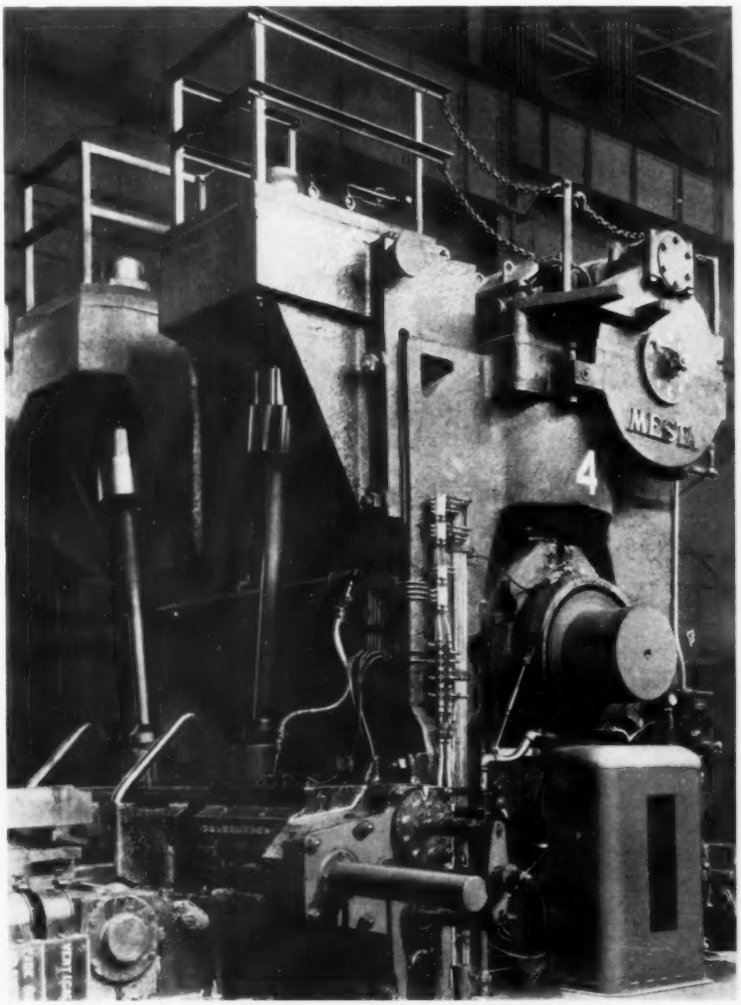
THE MATERIALS FROM WHICH GREASES ARE MADE

Greases contain four fundamental types of ingredients: fats or fatty materials, a base (alkaline material) which is added to bring about the saponification of the fat, oily material (usually a petroleum oil), and finally, additives and other special materials which impart special characteristics. The grease technologist in approaching the problem of preparing a new grease must consider each of these types of materials in order to select ingredients which will impart the desired characteristics to the finished product.

The soap phase of the grease which is to be prepared is composed of a fatty material which is chemically reacted (saponified) with an alkaline material. The effect of the fat and the base (alkali) must, therefore, be considered individually.

Fatty Materials

Fatty materials may be classified in several different ways. For the purposes of grease making, however, they may be classified as natural fats (glycerides), fatty acids, distilled fatty acids, modified fats and fatty acids, and synthetic fatty materials. Each of these classifications is in itself extremely broad. Space will not permit a full discussion of the many factors which affect the final choice of fatty material for a new grease. A few points of interest may however, be mentioned. Consider as an example the first classification, i.e., natural fats.



Courtesy of The Farval Corporation

Figure 3—A Mesta roughing stand showing details of the Farval centralized system of grease lubrication

Natural fats may be broadly classified as animal, vegetable, and marine fats. Animal fats may be classified by origin, i.e., horse oil, beef tallow, hog fat, etc. Each of these fats has definite characteristics. But within even these sub-classifications, important differences exist. On first thought, the

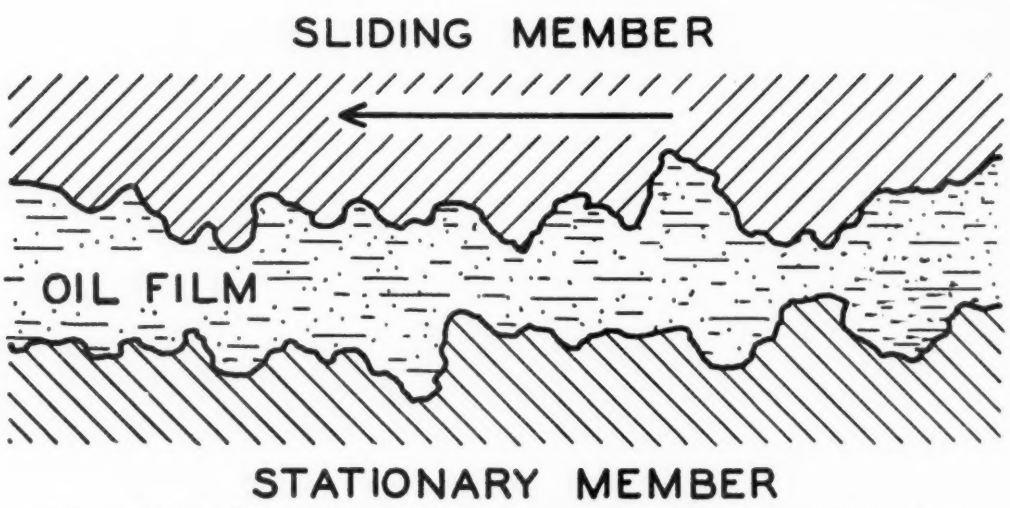


Figure 4—With thick-film lubrication the moving parts are completely separated by an oil film. The roughness of the surfaces are greatly exaggerated for purposes of illustration

average person would probably conclude that hog fat, for example, is hog fat the country over and that the fat from one hog is the same as the fat from any other hog. The grease maker knows that this is not the case. The suitability of hog fat for grease manufacture depends on the methods used in processing the fat and on the length of time and the conditions under which it has been stored prior to use. Even further, the characteristics of the fat depend to a certain extent on the feeding habits of the hog. Greases produced from the fat of northern hogs, for example, require a different ratio of oil to soap for a given penetration (hardness) than do greases prepared from the fat of southern hogs. The reason is, simply, that northern hogs feed on corn while southern hogs eat peanuts, cotton seed meal, and similar foodstuffs. As a result, the fat from southern hogs is less highly saturated (a technical term relating to the ratio of hydrogen to carbon in the fatty acid molecule), and the soap made from it is softer than the corresponding product from the fat of northern hogs. Differences of the magnitude spoken of here do not constitute a major problem since minor differences in fats may be determined by relatively simple chemical and physical tests and allowances may be made for these differences. They do serve to illustrate, however, some of the many factors which must be taken into consideration.

It can be readily visualized that if differences of this type are found in different lots of fat from the same species of animal, much greater differences are found between fats of different classification. In choosing the fatty material, the source, method of

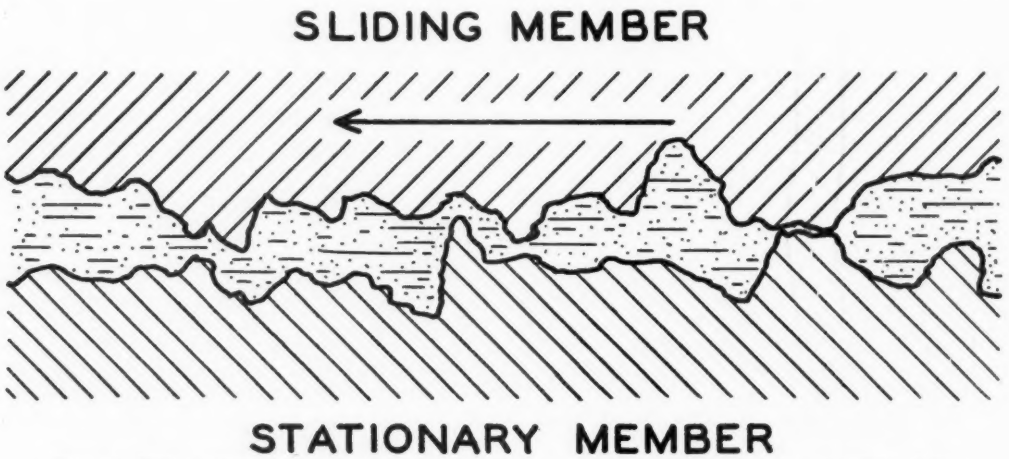


Figure 5—With partial boundary lubrication, the oil film is so thin that some of the high spots of the sliding member touch the high spots of the stationary member

Courtesy of U. S. Army

Figure 6—Light tank M-5. A condition of operation involving sand and high temperature

Courtesy of Allis-Chalmers Manufacturing Company

Figure 7—Showing how logging machinery must often operate in water, demanding a lubricant with high tenacity and water resistance

preparation, average molecular weight and molecular weight distribution, degree of unsaturation of the fatty acids, the chemical nature of the unsaturated acids, and a number of other factors, all must be considered. The fat chosen must contain enough saturated acids to give the desired soap-to-consistency ratio, yet must contain enough unsaturated acids to give proper stability. But the unsaturated acids must be of such type as not to deleteriously affect the oxidation stability of the finished product. Obviously, the choice of a proper fatty material is not a simple matter nor one which can be intelligently made without a considerable background of knowledge of the effects of various types of fatty materials on the characteristics of greases made from them.

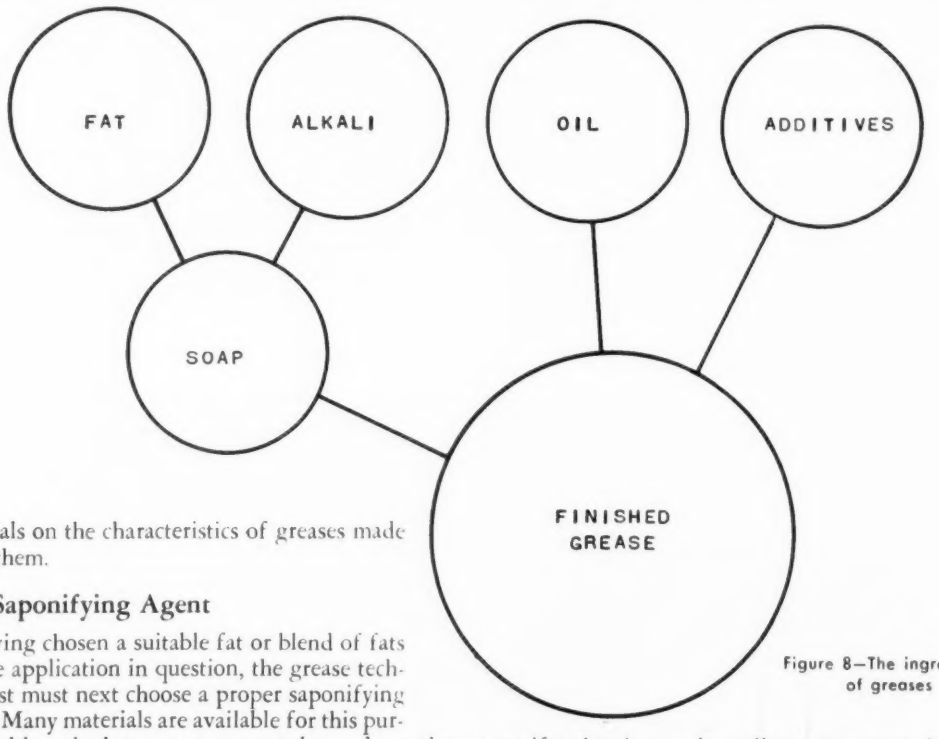


Figure 8—The ingredients of greases

The Saponifying Agent

Having chosen a suitable fat or blend of fats for the application in question, the grease technologist must next choose a proper saponifying agent. Many materials are available for this purpose, although those most commonly used are the oxides or hydroxides of sodium, calcium, aluminum[1], lithium, or mixtures of these materials. To obtain special characteristics, however, barium, strontium, magnesium, lead, potassium, copper, and a number of organic bases may be used alone or in combination with any of the forementioned types.

Sodium soap greases have good high temperature characteristics, but relatively low water resistance (although water resistance may be improved by the use of proper additives or by the proper choice of mineral oils), and have normally a fibrous texture which results in but little propensity toward channeling although it does result in relatively high torque because of the drag of the fibrous material.

Calcium soap greases have, generally, relatively low melting points but excellent water resistance; they are characterized by their buttery texture. They have, therefore, a much greater tendency toward channeling than do sodium soap greases, but in consequence have much lower torque than the corresponding sodium soap products.

Mixed sodium-calcium greases have properties lying between the two extremes with specific properties dependent upon the ratio of the two bases.

Aluminum soap greases have a gel-like texture, moderate water resistance, very good resistance to centrifugal action, and excellent appearance, but are limited in the temperature range over which they can be satisfactorily used.

Lithium soap greases have good water resistance, good high temperature characteristics, excellent low temperature characteristics, and a buttery to semi buttery texture, but require special manufacturing procedures and high cost ingredients which prohibit their use in all applications where cost is a limiting factor.

Already it is clear that a large number of soaps can be prepared by proper choice of fatty materials or blends of fatty materials and using the many different saponifying agents (or combinations thereof). The choice of a proper soap which will give a grease of the desired characteristics is oft-

[1]In the case of aluminum soap greases, usually the soaps are prepared by double decomposition rather than by direct saponification.

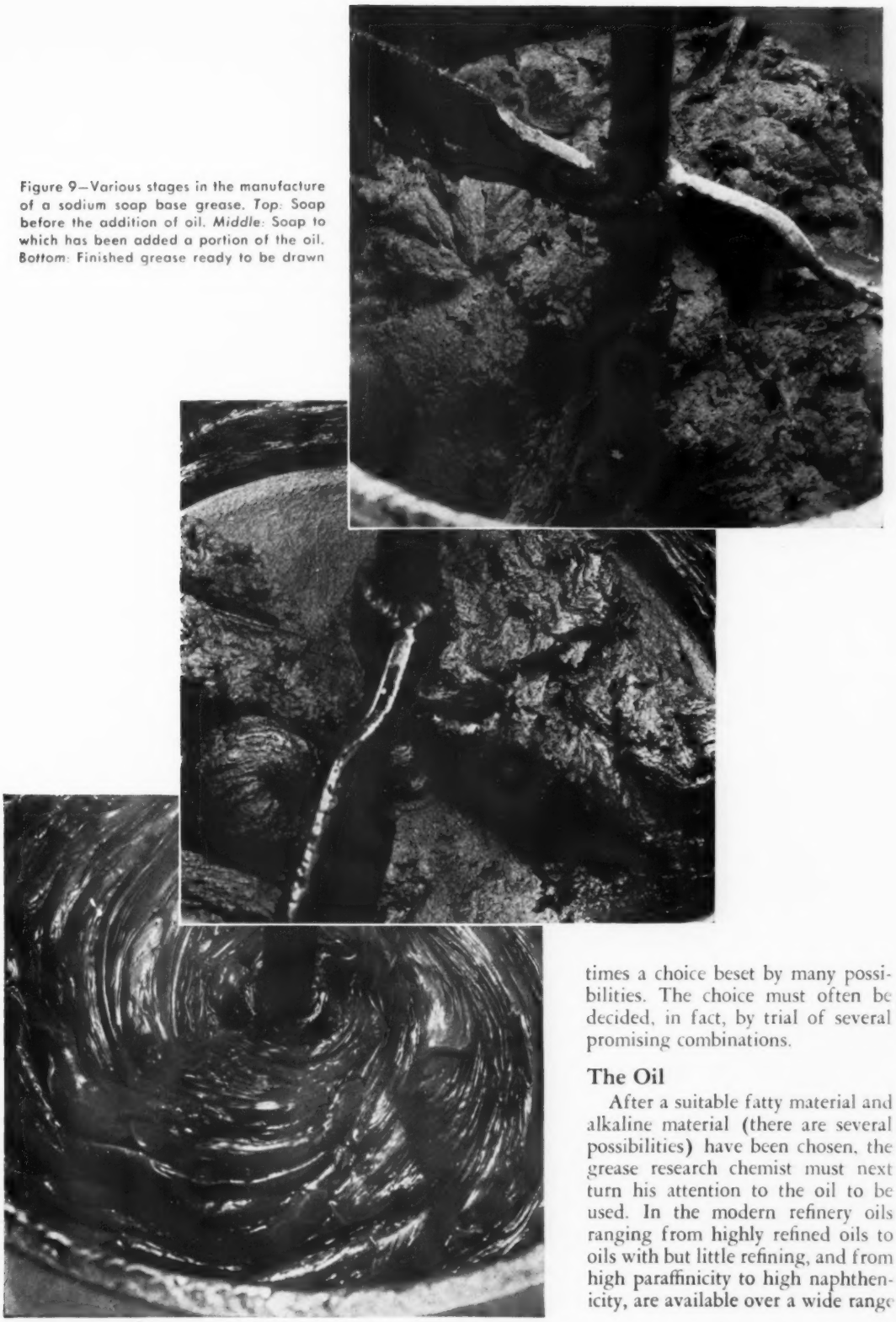


Figure 9—Various stages in the manufacture of a sodium soap base grease. *Top*: Soap before the addition of oil. *Middle*: Soap to which has been added a portion of the oil. *Bottom*: Finished grease ready to be drawn

times a choice beset by many possibilities. The choice must often be decided, in fact, by trial of several promising combinations.

The Oil

After a suitable fatty material and alkaline material (there are several possibilities) have been chosen, the grease research chemist must next turn his attention to the oil to be used. In the modern refinery oils ranging from highly refined oils to oils with but little refining, and from high paraffinicity to high naphthenicity, are available over a wide range

of viscosities from light distillate oils to heavy residual oils. Facilities are available in fact to "tailor make" an oil to suit almost any demand. And in addition, to impart special properties to the proposed grease, synthetic oils — materials prepared by the chemical ingenuity of man, which possess properties superior in some respects to the best efforts of Nature — may be used.

No set rules can be laid down for the choice of the proper oil. In general, however, the choice is based on the type of service for which the grease is to be used. For slow moving bearings under heavy loads, high viscosity oils are used; for high speed bearings under light loads, low viscosity oils are used. For bearings operating over long periods of time without relubrication, oils of high refinement and oxidation stability must be used; for bearings where leakage is high and relubrication is frequent, more economical oils of lesser refinement and lower oxidation-stability may be used. For bearings operating under high temperature conditions, oils of high flash point and high distillation range to lessen fire hazard and prevent evaporation losses may be necessary; pour point and viscosity index may be of little consequence. For bearings operating under extremely low temperature conditions, exactly the opposite will be true. Here again experimentation is usually necessary before a proper choice of oils can be made. Prior knowledge and experience are essential, but the best oil blend must be chosen by experimentation from among several potentially acceptable combinations.

Additives

Having chosen the basic fundamental units of soap and oil for his grease, the research chemist must then choose the modifying agents which he wishes to incorporate in his grease to produce special properties. The field of choice here too is broad. Not many years ago the use of additives in greases was almost unknown; today additives to give extreme pressure properties, high melting points, oxidation resistance, increased tenacity or tackiness, water resistance, foam resistance, and other properties are available in a hundred different modifications and are widely used. The additive (or additives) used must be chosen, of course, on the basis of the intended service. The character of a grease may be quite changed by the proper use of additives; a calcium soap grease which would have a typical buttery texture without additives may be changed to a tacky, stringy, product by the incorpo-

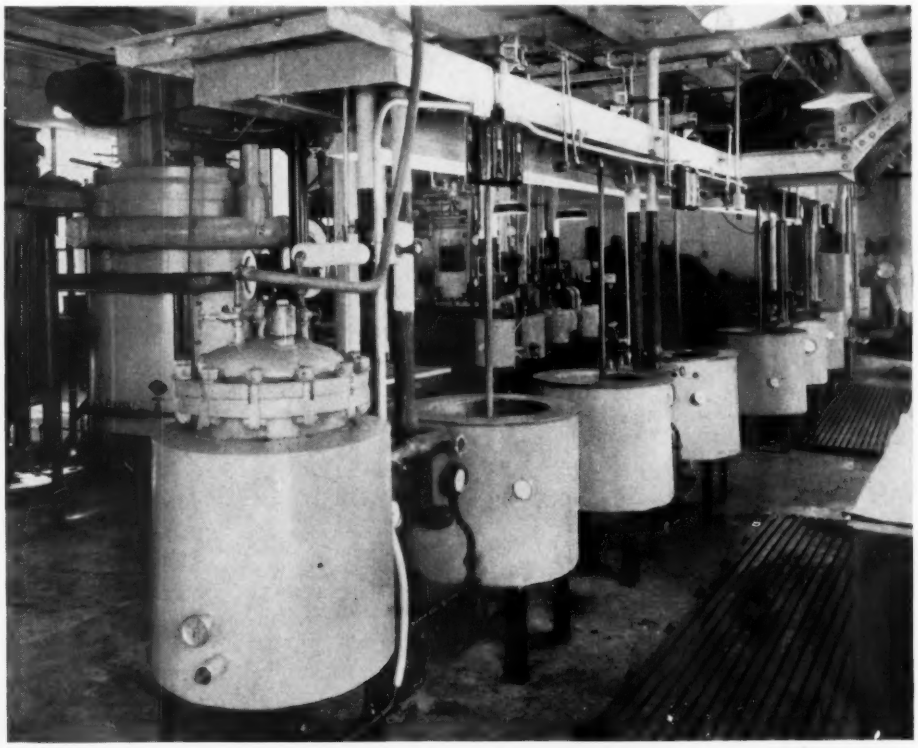


Figure 10—A modern grease research laboratory

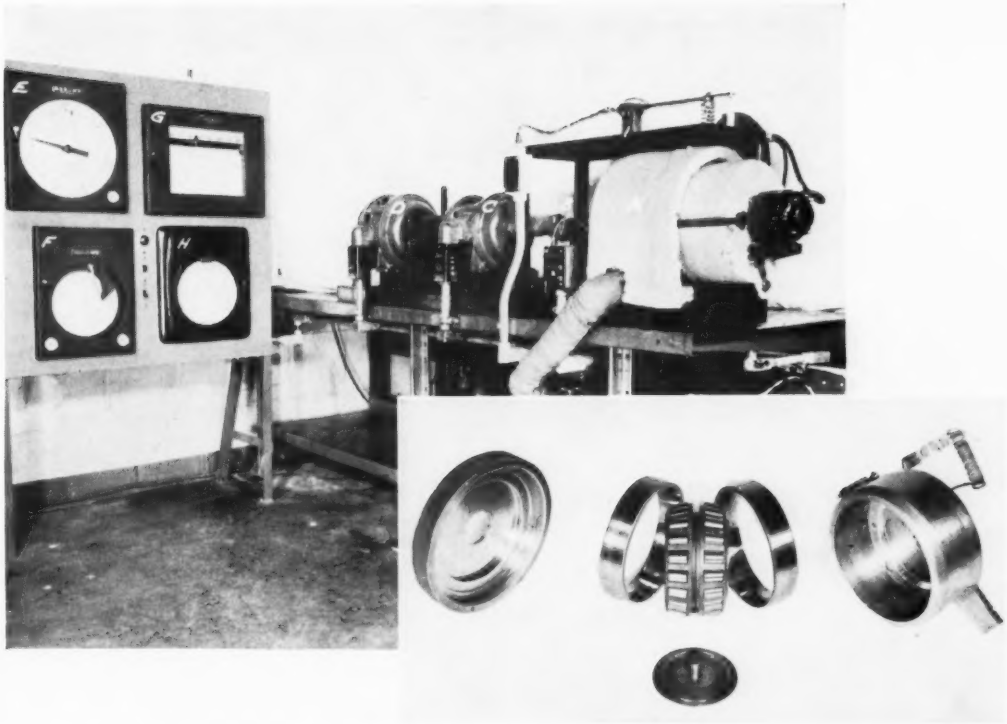


Figure 11—The torque-breakdown machine—a valuable laboratory device for subjecting greases to simulated operating conditions involving speed and temperature in ball or roller bearings

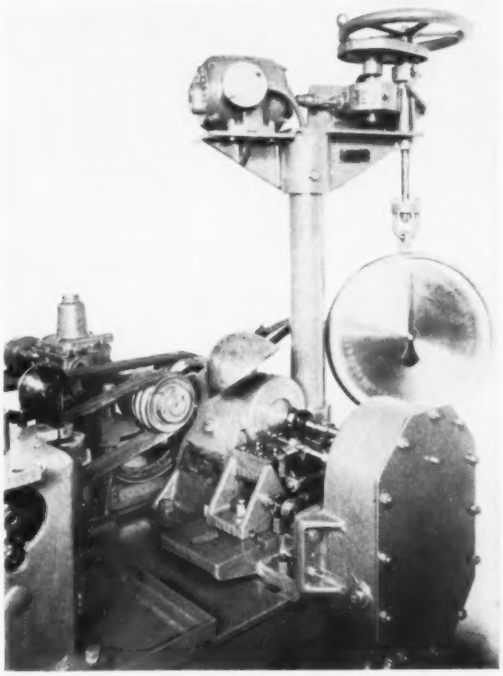


Figure 12—The SAE Machine, a device for measuring extreme pressure properties

Figure 13—The ASTM Penetrometer, a device for measuring the relative hardness of a grease

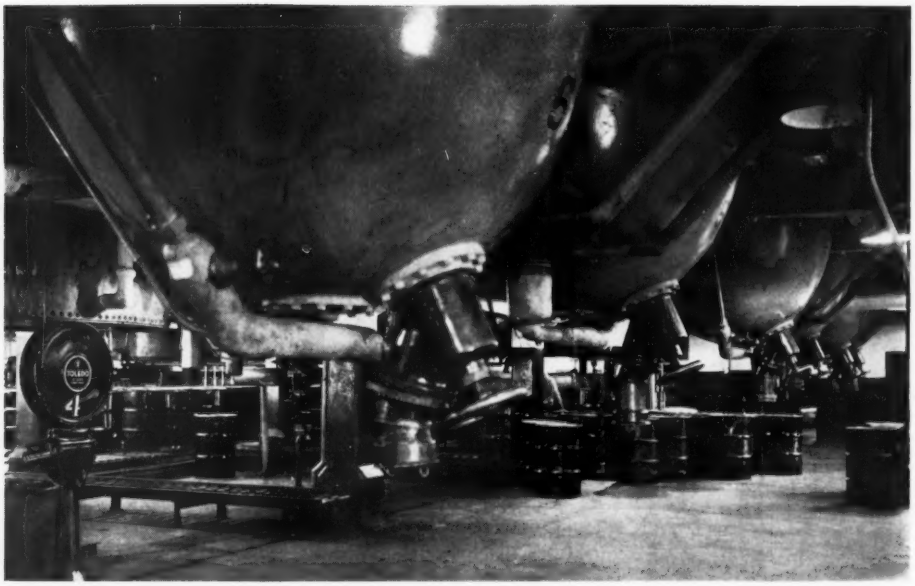


Figure 14—Bottom view of a set of grease kettles

Figure 15—The many oils used in grease manufacture are stored in large tanks near the grease plant

ration of proper materials. Needless to say, the choice is one of great importance. Decision as to the use of fillers must also be carefully made — graphite, metallic dusts, fiber, etc.—which although not commonly used, do fulfill a specific need for special purposes.

Number of Possible Greases

A moment's consideration will show that the number of possible combinations of all the fats, bases, oils, and additives is almost without limit. Aside from the possible combinations of known materials, however, cognizance must be taken of the applicability of materials not previously used. With the increase in demand for greases of new and unusual character, the grease maker must continually search for new materials to supply characteristics not available with the usual ingredients. This is, of course, a whole field of research in itself, but is, nevertheless, a factor which must be taken into consideration in the preparation of a new grease.

It is easily understood, then, that even after a choice of materials has been made, a considerable amount of work remains to be done in the laboratory. For example, if the research chemist decides to use as a fat blend in one type-formula a blend of hydrogenated fish oil and tallow, he still cannot say without trial whether the best results will be secured with a 50-50 blend, a 40-60 blend, a 60-40 blend, or some other ratio. He may determine that an oxidation inhibitor will be required, but the best of several inhibitors and the optimum concentration of the best inhibitor must be determined by trial. So too, the manufacturing conditions to be used must be determined. There is no standard manufacturing procedure which will suffice for all types of grease. Sodium soap greases, for example, are normally fibrous in texture; but by using the same ingredients and varying the manufacturing procedure, greases which are fibrous with long fiber, fibrous with short fiber, ropy, semi-buttery, or buttery, may be produced.

And so the new grease moves from the theoretical to the practical and experimental work is begun.

The Grease Research Laboratory

The modern grease research laboratory is an interesting place, with its kettles, scales, special mixers and other devices used in the modern compounding of greases. A multitude of test equipment is at hand — devices for measuring consistency, high temperature characteristics, leakage characteristics, extreme pressure properties, oil separation tendencies, and a number of other attributes vital to proper performance of the lubricant.

With this equipment experimental production and testing of greases is carried out. Many experimental batches are required — sometimes hundreds of batches — and many tests are necessary on each

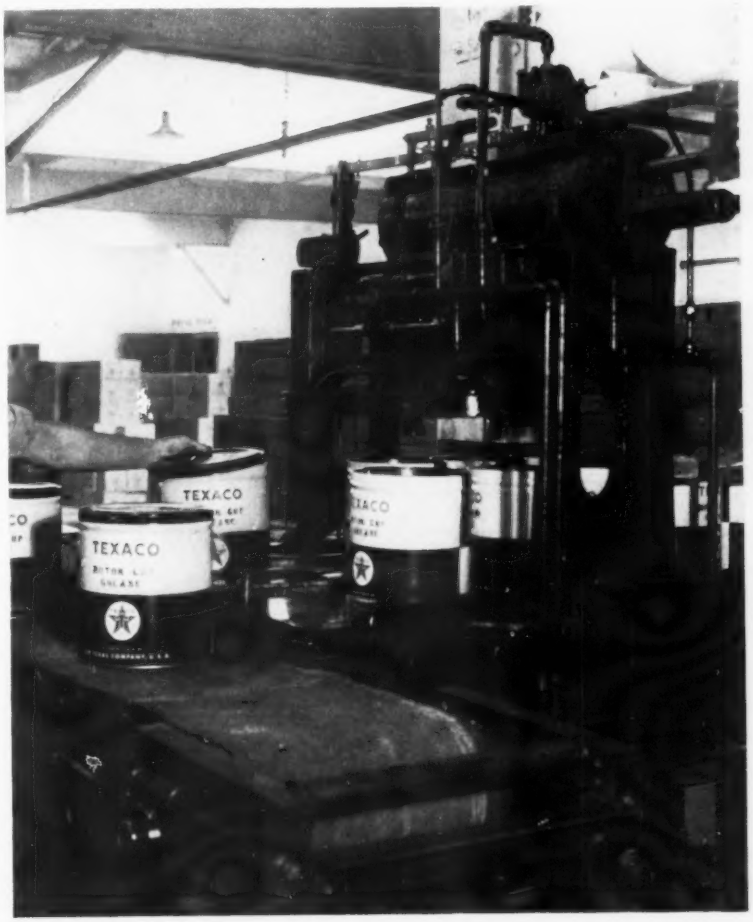


Figure 16—Twenty-five pound can filling machine. Covers are placed on the cans immediately to prevent possible dirt contamination.

promising product. The mass of data thus accumulated must be subjected to careful analysis. Trends are established and pushed through to conclusion. The good is accepted; the bad is rejected. Gradually, by trial and elimination several promising products emerge.

The Field Test

Although laboratory tests are useful, field conditions often impose demands on the lubricant which cannot be foreseen or exactly duplicated in the laboratory. The most promising products must then be tried in operating equipment.

For the field trial a sufficient supply of the test grease is prepared in the laboratory and shipped to the site of application. The research chemist too, journeys to the scene of the trial in many cases. Here the grease is applied and its performance is closely followed, by the operators of the device, and by technical personnel. In the usual case, the best of the several products submitted can be determined. In the unusual case this best product is entirely satisfactory. Sometimes the lubricant is found deficient in one or several minor respects. In spite of broad experience and accuracy of work, all factors cannot be foretold. If the product is satisfactory it is ready for large scale production. If it is not, it must be returned to the laboratory for another period of trial and testing to bring about the modifications found necessary or desirable, and subjected to a second field test.

Plant Manufacture

Whether on the first trial or a subsequent trial, a satisfactory grease is finally found, plant scale manufacture must be then undertaken. The conversion to large scale preparation, naturally, must be studied and planned. Manufacture of 10 or 50 pounds of grease in the laboratory is one thing; manufacture of 10,000 or 50,000 pound batches in the plant may be quite another. Laboratory kettles are made to be small counterparts of the plant kettles. But differences do exist and these differences may require small changes in the ratio of ingredients or processing cycle. Plans must be made to deliver large quantities of materials to the plant grease kettle at the proper time and in proper proportion. Often new tanks for storage, new lines, and new pumps are required. In a few cases it may be necessary to design entirely new equipment to handle satisfactorily the manufacture of the new product.

In most cases, a mass of detail must be handled for the conversion; but most can be resolved on the basis of past experience. If plans are properly laid, the required product is satisfactorily made on the first attempt. It is tested, packaged, and shipped.

Figure 17—The finished grease, packaged in drums ready for shipment

THE END OF THE STORY

That is the story of a new grease, raised at last to its full status as a regular product. The story does not end here, however. The performance of this product, and all regular products must be carefully followed by field engineers. Through the years, modifications and improvements must be made to keep pace with the mechanical growth and progress of the equipment to be lubricated. No one can tell for how long the product will be manufactured. Entering an era of super speeds and atomic power, it seems certain that new greases will be constantly demanded, and that many of the products now manufactured will be no longer useful.

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More than 300 million pounds of Marfak sold

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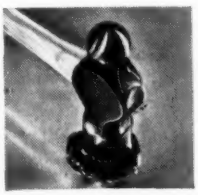

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S-T-R-E-T-C-H TEST — shows how *Marfak* holds together where ordinary grease would come right apart. *Marfak* doesn't work out of bearings . . . gives better protection . . . reduces wear . . . prevents rust . . . assures longer life for parts.

RUB TEST — shows how *Marfak* liquefies to a tough film that means effective lubrication, while it retains its original cohesiveness at the edges. This "collar" at the edge of a bearing seals out dirt and moisture . . . assures longer bearing life.

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